Leibniz Institute for Astrophysics Potsdam

The Einstein Tower in Potsdam

Final Report 2018

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Keeping It Modern

Final Report 2018

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The Einstein Tower

The solar observatory "Einstein Tower" on the Telegraphenberg in Potsdam is a unique landmark of expressionist, utopian, and symbolic architecture at the beginning of the 20th century – initiated by the astronomer Erwin Finlay Freundlich (*1885 – †1964), designed by the architect Erich Mendelsohn (*1887 – †1953), and supported by Albert Einstein (*1879 – †1955). The Einstein Tower was constructed after World War I facing economically challenging times (postwar reconstruction and hyperinflation). The new solar observatory was financed in equal parts by the state of Prussia and the Albert Einstein Foundation of the German Industry. The structural work was completed in the summer of 1921 and, with installation of the vertical telescope (inner tower scaffolding) and horizontal spectrograph, observations started in December 1924.

The Einstein Institute with Freundlich as director was in charge of the Einstein Tower from 1920 to 1933. With the take-over of power by the National Socialist Party in 1933, first Einstein's name was removed from the institute by renaming it into Institute for Solar Physics, and soon thereafter the observatory was absorbed and integrated in the Astrophysical Observatory Potsdam (AOP). After World War II, the Einstein Tower belonged to the German Academy of Sciences (in 1946), the Central Institute for Solar-Terrestrial Physics/Heinrich Hertz Institute (in 1967), and the Central Institute for Astrophysics (in 1983). Following the German reunification, the solar observatory became part of the Astrophysical Institute Potsdam (1992), which was renamed to Leibniz Institute for Astrophysics Potsdam (AIP) in 2011.

The historic roots of AIP, the current owner of the Einstein Tower, are the Berlin Observatory founded in 1700 and the Astrophysical Observatory Potsdam established in 1874. The main site of the Institute and home to its 190 employees are the grounds around the former Babelsberg Observatory (1913), which is also part of the UNESCO "Prussian Castles and Gardens" World Heritage Site. In addition, the historic ensemble of buildings maintained by AIP includes the Great Refractor (1899) located next to the Einstein Tower. After the German reunification, the Institute was established again in 1992 as a foundation under civil law and belongs nowadays to the Leibniz Association. The 86 member institutions of the Leibniz Association are funded in equal parts by the federal and state government(s). As one of the largest institutes for astronomical research in Germany and the largest in Eastern Germany, AIP carries out fundamental astrophysical research covering the Sun, the stars, the Milky Way, and other galaxies, as well as cosmology. Situated in the Berlin/Potsdam metropolitan area, AIP assumes a very prominent role as an advocate and communicator of astronomy and astrophysics and as a contact point for politics, business, and industry.

North-west view of the Einstein Tower with open dome facing the Sun.
(Credit: Jürgen Rendtel)

The Einstein Tower is still in use as an optical laboratory equipped with a high-resolution spectrograph fed by a powerful light-gathering solar telescope with a clear aperture of 0.6 meters. In addition, telescope and spectrograph are used to train graduate and PhD students of the University of Potsdam and the Institute. The observatory is open to the public during annual events like the "Long Night of the Sciences", an open-house event, where many research institutes and universities in Berlin and Brandenburg participate. Guided tours for groups, in particular school classes, are coordinated by AIP's press and public outreach office. Interested individuals can participate in public tours across the entire historic Telegraphenberg campus offered by the Urania Potsdam, which include the Einstein Tower. Because of the unique characteristics of the building and its history, the Einstein Tower is featured in almost every book on modern architecture. The science park "Albert Einstein" is open during daytime hours, inviting everyone for a visit to see and experience the Einstein Tower, may it be architects or interested laypersons.

All historic buildings of the Science Park "Albert Einstein" at the Telegraphenberg Potsdam, including the Einstein Tower, are catalogued in the "List of Monuments in the State of Brandenburg" (Denkmalliste des Landes Brandenburg) as of 2013 December 31 under the common identification number 09156548.

History and Significance of the Building

The Einstein Tower is the first solar tower telescope in Europe, which builds on the experience of this type of telescope at the Mt. Wilson Observatory in California. However, telescope and spectrograph, i.e., the experimental setup of the solar physicist, are no longer vertically aligned but the spectrograph became horizontal, ultimately leading to the unique form of the Einstein Tower – a beautiful example of form follows function. The open structure of the Mt. Wilson towers was rejected, and the architect Mendelsohn was free to create the structure encasing the telescope on a double-stacked wooden tower with a separate foundation and the horizontal spectrograph in an insulated room, partially below ground to provide a stable thermal environment for precision spectroscopy.

The organic, continuous, and sinuous natural forms of the Einstein Tower's hull were inspired by the paradigm shifts brought about by modern physics at the onset of the 20th century, i.e., quantum physics and the theory of relativity and gravitation. The latter provided the motivation for Freundlich to initiate the collaboration with Einstein already in 1911 searching for observational evidence of Einstein's theories, by measuring the relativistic redshift of solar spectral lines in the gravity field of the Sun, and seeking support for a modern solar observatory. Undoubtedly, it was the strong engagement of Freundlich that popularized the Theory of Relativity among the astronomy and astrophysics community.

Interior of the dome with the two coelostat mirrors (left) and stair case to the platform that provides access to the 60-centimeter lens (right). The double-stacked wooden tower to the right protects the telescope from vibrations and minimizes thermal expansion preventing focus drifts. (Credit: Jürgen Rendtel)

Mendelsohn was in the early 1920ies one of the most visible proponents of modern architecture creating some unusual and enthralling buildings. Reinforced concrete as a new building material inspired Mendelsohn's sketches of Einstein Tower, which were first shown publically in the exhibit "Architecture in Steel and Concrete" in the autumn of 1919 at Paul Cassirer's gallery in Berlin. However, realizing the building structure proofed to be challenging, may it be to the poor quality of reinforced concrete at the time or because of inexperience with this new material. As a result the casing of the Einstein Tower is a mixed construction of bricks with thick layers of rendering combined with steel reinforcements. The addition of a grainy spray rendering coat and the absence of sheet metal for window sills, roofing, and rain spouts should nevertheless reinforce the impression of a building entirely realized in concrete, transcending the limitations imposed by traditional construction materials and methods. Mendelsohn's vision also extended to the interior design with winding spiral staircases leading up to the observing platform and down to the basement laboratory, with lighting fixtures and angled windows providing a dynamic illumination patter of light and shadow, and even with furniture providing an esthetic work environment.

Current Condition of the Building

The mixed construction of the Einstein Tower is the underlying cause for the recurring damage pattern. The concrete quality and iron reinforcements do not conform to current standards, and no efficient way to remove rain water and humidity was available leading to fissures in the rendering coat, which facilitate an easy entry of rain water and moisture. This caused damages after freezing temperatures and corrosion of the iron reinforcements (structural members) above the windows and throughout the building structure.

The first major renovation in 1927 because of widespread moisture penetration commenced under the supervision of Mendelsohn himself leading to a massive addition of sheet metal (window sills and roofing) significantly changing the character of the building. These measures, however, were not very effective necessitating major repairs about every 5–10 years.

Small cracks on the exterior walls and spalling along the window sills (left). The crack allowed water to penetrate into the building, which is visible as a chain of water droplets at the top of the window linings (middle). The temporal evolution of cracks is monitored with precision markers (right). (Credit: Jürgen Rendtel)

Regrettably, the history of the Einstein Tower is also a history of recurring damages and endless renovations. The second major overhaul in 1940/41 was driven by fungal infestation that damaged the prism spectrograph in 1937. Towards the end of World War II, a blockbuster detonation during an air-raid in proximity to the Einstein Tower severely damaged entrance, dome, windows, doors, and even interior walls. However, immediate repairs in 1946/47 allowed solar observations to continue soon thereafter. Major repairs of the building followed in 1950, 1958, 1964, 1974–1978, and 1984. By the beginning of the 1990ies the condition of the Einstein Tower deteriorated to the point, where the continued existence of the building was endangered.

Intensive research into the origin and causes of the recurring damage pattern preceded the latest major repair, which was made possible by generous support (about 2 Million Euros) of the Wüstenrot Foundation and was completed in 1999. The company Pitz & Hoh, Werkstatt für Architektur und Denkmalpflege GmbH, Berlin (architects and experts for monument conservation) prepared a comprehensive report in 1996 documenting the damage pattern and investigating the underlying causes including extensive studies of the elasticity of the rendering. The restoration was carried out in close collaboration with State Office for Monument Protection (Landesamt für Denkmalpflege) and included: renewal of the rendering coat conserving the original rendering whenever possible, return to ochre-colored painting of the render, removal of the ineffective sheet metal installed in 1927, returning the dominant entrance terrace to its original appearance, and elimination of dampness and moisture damage in the basement. The guiding principles of the renovation and restoration were to preserve the artistic and corporeal substance of the Einstein Tower as much as possible, to facilitate easy access and procedures for future repairs, and to safeguard the building while upholding its function as a place for astrophysical research. At the end of the renovation it became evident that continuous monitoring and repairs will be required in the future. This led to a long-term conservation plan because causes for damage could not be completely removed but only mitigation plans were put into place. Keeping the architectural monument Einstein Tower alive will require significant efforts in the times to come.

Build-up of biological materials (moss, algae, lichen, …) over the winter month affecting exterior walls and sheet metal roof covers. One of the most problematic parts is the rainwater drainage and the interface between the sheet metal roof and the vertical structure of the tower, where rainwater enters the building. (Credit: Jürgen Rendtel)

Restoration of Landscapes Surrounding the Einstein Tower

The landscaping architect Dipl.-Ing. Daniel Sprenger evaluated the surroundings of the Einstein Tower including the grass covered subterranean laboratories. The landscaping architect developed a detailed conservation plan, which also summarizes the tasks that have to be completed to restore and preserve parts of the exterior, paths around the building, and surrounding gardens. These measures are already discussed with and approved by the Landesamt für Denkmalpflege in Brandenburg.

The major goals for preserving the landscape surrounding the Einstein Tower and the grass covered part of the building are:

- Lasting preservation of the grass covered part of the building and establishing a more suitable type of resistant vegetation
- Ensuring a proper drainage of rainwater
- Reestablishing the proper surfaces of the paths around the Einstein Tower
- Maintenance concept for the surrounding trees and forest border

Originally, the Einstein Tower was a solitary building at the southern part of the Telegraphenberg. No trees were in the immediate surroundings of the tower, which is now enclosed by forest (oaks and rubinia) on three sides. These trees have reached a height of about 15 meter over the last 90 years. A rectangular paths leads around the building and hedgerows emphasize the rectilinear character of the whole arrangement including the 20–40 cm body of soil above the laboratory and spectrograph room ceiling and their backfilled walls. The steepness of the grass covered walls and their underlying honeycombed plastic reinforcements are problematic with regard to structural integrity.

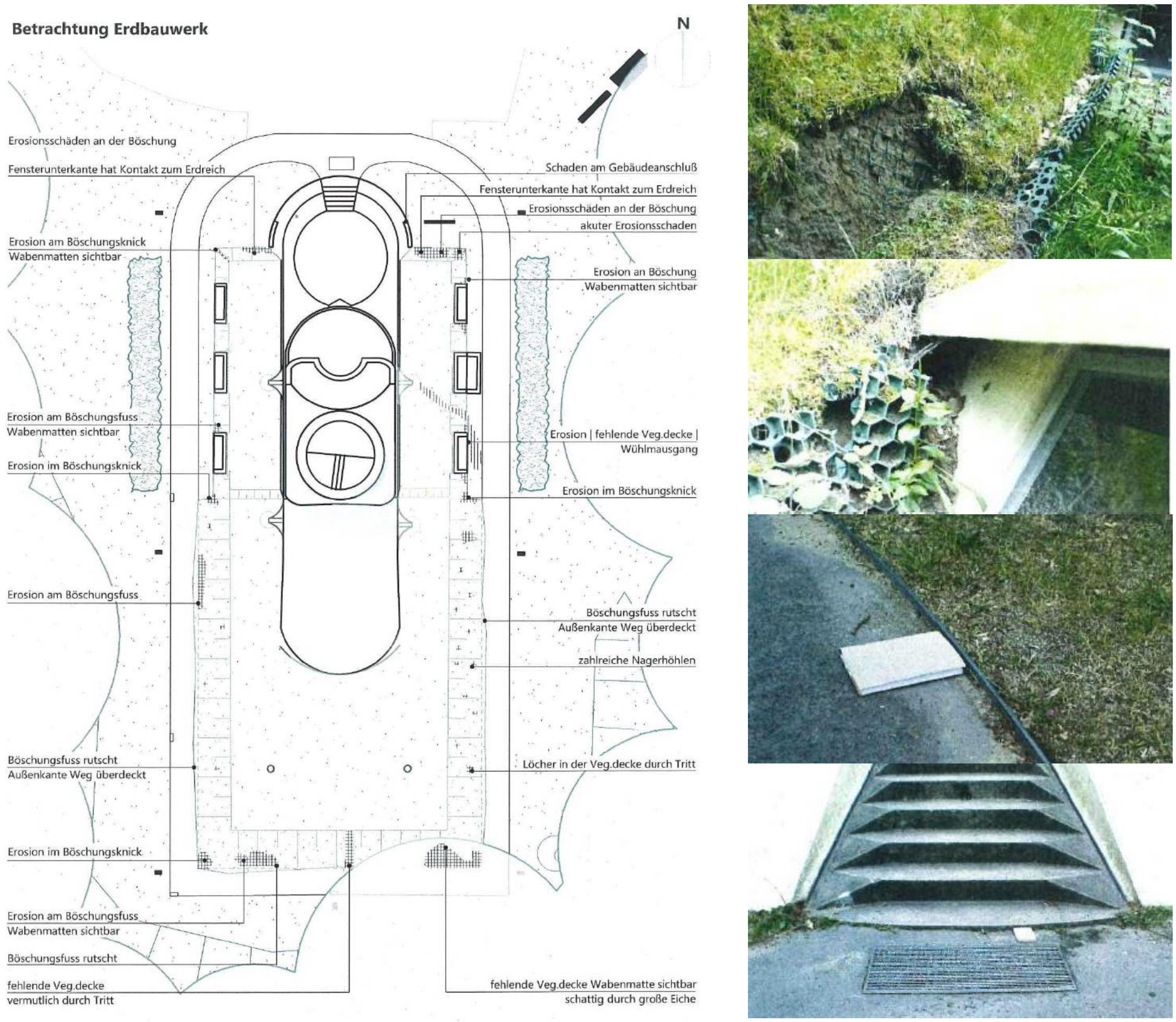
The grass covered walls show clearly traces of erosion on all sides. Slides and wash-outs uncovered in many places the installed honeycomb mats, which were placed below the turf to avoid surface erosion. Especially in areas with a slope of 1:4 at the North side and in areas of the embankments, the honeycomb mats are exposed in large areas. In particular, the interfaces between turf and windows exhibit erosion damage. The installation of an insufficiently stable body of soil led to slides and wash-outs along the entire length of the embankments. The bottom of the embankment "migrated" downwards even beyond the borders of the paths (stabilized by some steel bands) leading around the building. Rodents dug numerous holes into the embankment, especially on the west side. Further damages are caused by unattended visitors of the Einstein Tower, who climb up the embankments to get a glimpse of the interior. Parts of the honeycomb mats are now uncovered as a result.

The recorded damage to the body of soil is partly significant. One reason for the strong erosion damage consists in the insufficient stability of the substrate. The superficial protection against erosion with honeycomb mats works well with embankment slopes of 1:1. However, a slope of 1:4 is too steep so that the entire backfilled embankment has shifted. This process has been compounded by the absence of a continuous wire mesh protection against rodents so that a system of burrows additionally destabilizes the embankment.

The vegetation cover is present almost everywhere and has adapted well to local conditions. In the shaded areas under the dense tree tops, mosses predominate against the grasses and ferns, and tree seedlings (mostly oak seedlings) are widely spread. The turf is permeated with numerous herbs. The vegetation system covering the body of soil shows significant signs of hyperacidity. In the past 90 years, the Einstein Tower became surrounded by up to 15-meter high trees. The microclimatic conditions, which are altered by increasing shading, place a burden on the structure. The hedgerow of guelder rose (viburnum opulus) on both sides of the building are shortened in comparison to their original placement and thinned out at the bottom.

The vegetation cover is in good condition due to the regular care. The colonization of seedlings and herbs can be easily countered with the regular care procedures. In order to prevent acidification, the water balance and the supply of calcium and magnesium must be improved. The tree population should be reduced to minimize the shading of the structure. Removal of the closest trees should be considered if permitted by environmental protection laws. The hedgerow has to be supplemented and filled in. Regular trimming and pruning will reestablish a uniform appearance of the hedgerows.

The surface material of the bituminous path is largely worn away, and the originally bright appearance of the cover has been lost. The two-sided steel straps rise now up to 2 cm above the surface and prevent rainwater from draining laterally. A stumbling edge is now present cause by the grating just in front of the entry stairs. This grating is not contemporary, and it is disruptive in geometry and appearance. All four drainage gratings under the rainwater spills, including the connection pipe, are clogged with sand, leafs, and soil. The connection point of the rainwater pipes is not known. A controlled drainage of the rainwater is no longer guaranteed. The small drainage covers along the paths are clogged with foliage and earth. The connection points are not known. They are in no working condition. The water-bound path leading from the north to the observatory shows strong erosion damage. The grain size and mixture of the surface material is not suitable for this inclination and is flushed down the slope. The cobblestone troughs are uncovered and impaired and have become ineffective.



Damages related to the earth cover of the spectrograph room and the surrounding landscape, which includes erosion of the walls, especially where the slope is very steep, destruction of the honeycomb support structure, rodent burrows, and washed-out surface covers of the surrounding paths. (Credit: Dipl.-Ing. Daniel Sprenger)

The missing surface coat of the paths has to be reinstalled. The overhanging steel edge must be adjusted to conform to the slope. The drainage systems for the roof water are not functional, the rainwater accumulates on the basement roof and leads to the growth of moss within the grass cover, which accelerates the erosion in the slope area. The system of open drainage channels along the way are not functional, and the connection of the existing drainage pipes has to be clarified. The paths between the astrophysical institute's buildings are made of water-based, fine-gravel surface coating, which is not sufficiently stable and largely destroyed by erosion. The transverse drainage grooves are exposed, and the concrete reinforcements also lay open and create a risk for accidents.

Recommendations

In order to permanently produce a stable embankment, the material of the backfilled wall must be replaced in accordance with the requirements of the guideline by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL) for roof greening. Embankment areas with a slope of more than 1:2 require additional engineering solutions for slope stabilization. It is necessary to clarify the extent to which the body of soil is a valuable original substance. Depending on the material, some of the soil could be retained in non-erosion areas.

The vegetation roof cover has to be restored and maintained continuously. A covering with rolled turf of the appropriate type and composition offers itself to achieve quickly a visually attractive appearance. The experience shows, however, that in the case of heterogeneous sites, as in the case of changing exposures to sunlight and rain as well as different slope inclinations, a seeding, for example with the help of a seed-impregnated geotextile, produces a powerful vegetation cover in the long run.

Slanted reinforced earth walls are proposed for producing the embankments. In order to follow the sophisticated architectural design of Mendelsohn, the use of auxiliary forms is necessary. The honeycomb mats (or similar geogrids) must be designed for the reinforcement of mineral layers and to ensure the separation and drainage function. The gravel or other bulk solids must be properly chosen in terms of grain distribution and material properties adhering to the static calculations of the reinforced earth construction. The function of the body of soil is to provide a roof greening of the laboratory rooms below. Since the greening is provided as a lawn, a base layer of material according to the FLL guideline for roof greening is proposed. This provides adequate stability, drainage, and substrate for vegetation growth.

The top layer of the surrounding paths has to be restored, the new top layer of bonding agents is based on reaction resins and bright natural stone gravel, which will be applied to the cleaned path in a thickness of 3–6 mm and then rolled and compacted. By using different rock splinters the design can be adapted to the special requirements of the monument. The coating is again fully usable after application. The side frames made of steel band must be adapted to the upper edge of the paths. The gradient of the path appears sufficient to guide rainwater over the surface into the adjacent lawns and to seep away. The existing drainage can likely be cleaned and rebuilt. The stumbling step at the main entrance disappears after the application of the new top layer. The height of the metal foot scraper grid should be adjusted or removed completely. The rainwater drainage system regularly requires revisions, so that the proper drainage of the roof water is ensured.

Summary

Embankments. At least in the region of the embankments, the body of soil is to be replaced by a suitable layer-stable material. In addition, the embankments must be protected against penetrating rodents. Embankments with a slope of more than 1:2 require additional engineering measures: we propose a design as a reinforced earth wall.

Roof greening. The roof greening of the laboratories is a characteristic element of the Einstein Tower and forms a lasting erosion protection. The local conditions changing on small scales require a careful selection of suitable turf, irrespective of whether rolling turf or seed-impregnated geotextile is chosen.

Drainage. The roof outlets have to be regularly maintained to prevent water erosion in the embankments.

Trees. The microclimatic conditions, which are altered by increasing shading, are a burden on the structure. The tree population should be cleared as far as possible in order to reduce the shading. This part of the recommendation was already implemented in early 2018 by cutting several trees, in accordance with environmental protection laws, and by removing significant undergrowth.

Surrounding paths. The eroded upper layer of bright natural stone gravel is to be restored. The drainage of the paths has to be ensured by sideways discharge into the vegetation areas.

Hedgerow. The rear body of the hedgerow has to be completed and the original contour cutting has to be observed.

Hygrothermal Simulations

In 2016, Prof. Dr.-Ing. John Grunewald and Dipl.-Ing. Hans Petzold joined the project. Prof. Grunewald leads the Institute for Building Climatology at the Technical University Dresden (TUD). The work package of the numerical simulations is contracted to the GWT-TUD GmbH in Dresden, a research and development service company supporting researchers of the TUD. The three major deliverables of the work package are hygrothermal simulations and risk assessment, guidelines for heating and air circulation, and installation of data capturing devices.

Introduction

Including the entire Einstein Tower in numerical simulations is impracticable. Therefore, the simulations focused on three details: a fissure in the exterior wall of the tower at a height of about 10 m, the exterior wall at the height of a sand joint at the transition to brick construction, and the concrete ring carrying the telescope dome above the upper office. The goal is an assessment of the risks arising from the environment and climate (solar radiation, rain, etc.) leading to cracks and fissures. The expected results are guidelines for the conservation plan to prevent damages to the building or at least to minimize their impact by early detection.

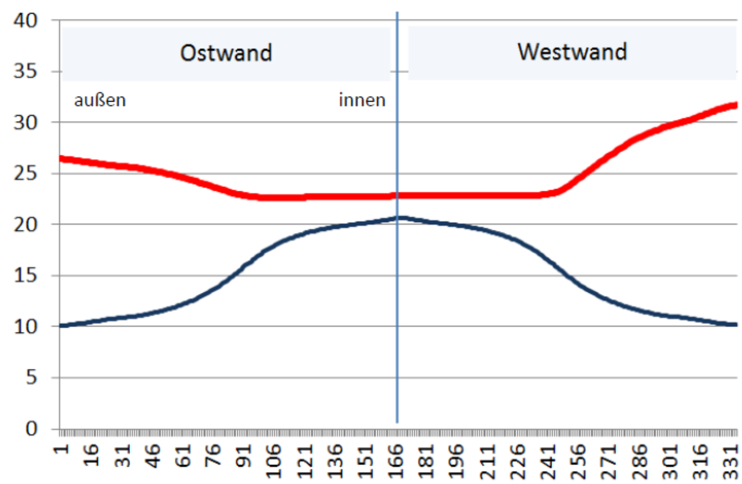
Key parameters for the study are the material properties, climate data, and the geometry of the simulated building parts. Characteristics of material were extracted from the documentation of the Einstein Tower's renovation in 1997–1999 and from a data base (MASEA) of historic construction materials. Additional laboratory measurements complemented these data. However, the uncertainties remain high because hygrothermal properties (heat conduction, heat capacity, moisture storage, moisture transfer function, etc.) of many material classes are still unknown or only broadly characterized. Other uncertainties concern the status of reinforcements, undocumented changes of materials during the many renovations, and the effects of already existing damages.

Non-stationary temperature, humidity, and radiation data were used as climatic boundary conditions on the basis of the test reference year (TRY) as well as the measured data of the German Weather Service (DWD) for the specific location. The impact of the solar radiation on the temperature conditions of the building structure depends on the diffuse and direct radiation, but on the other hand it is diminished by the surrounding trees as a function of the Sun's elevation. Finally, the absorption coefficient of the tower surface has to be considered. The bright painting of the Einstein Tower reflects a large part of the incident radiation. For white paint coefficients of 0.15–0.25 are given in the literature. For our calculations, coefficients of

0.3–0.4 were used. The value of 0.4 is clearly on the safe side because it is at the upper limit of the transmitted energy. A light paint coat is, of course, also favorable for stable climatic conditions in the tower. However, superficial humidification by rain and algae growth becomes thus also more quickly visible (see below). The height of trees is somewhat below the height of the tower. Their distance is about 6–10 m. The reduction of the radiation by the surrounding trees was initially not considered, again to be on the safe side. In addition, the shading is less pronounced in the upper part of the tower.

The geometry was approximated as far as necessary to work with the simulation software DELPHIN with rectangular element sizes. If measured values of the surface temperatures are available, these can be used directly. Overall, uncertainties are quite high. Therefore, an absolute evaluation cannot be expected. On the other hand, assuming comparable boundary conditions, relative assessments of structural details are meaningful.

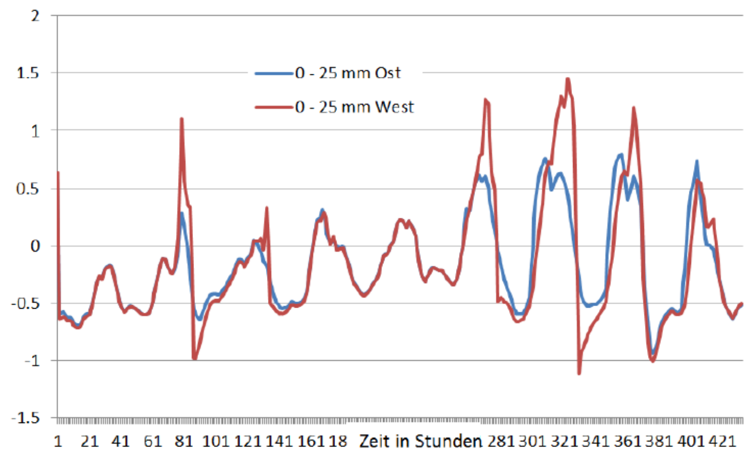
Tower Wall at a Height of 10 Meters



Maximum and minimum temperatures (°C) over the wall cross-section (millimeters) for east and west walls within a period of 30 summer days. The interior of the tower is not shown, to the left of the vertical line the east wall, to the right the west wall. (Credit: John Grunewald and Hans Petzold, TU Dresden)

At the tower, a horizontal crack is visible in the west wall at the window level above the first platform, both inside and outside. If it passes through the entire wall is not certain but likely. It had to be determined why this crack is present on the west side only but not on the east side at the analogue place. A one-dimensional simulation was carried out assuming a non-stationary interior and exterior climate. Air temperatures on the outside are the same, but the radiation and the impact by driving rain are different. On the west wall about 6 K higher maximum temperatures occur, since here the solar radiation is superimposed upon the higher outside air temperature in the afternoon. Since the inner temperature of the tower reacts slower and is approximately the same for the east and west walls, a higher stress on the west wall is likely. This is also visible in an inspection of the temperature gradients.

On days with direct radiation, the temperature gradient in the west wall is significantly higher. In the middle of the plotted period, two cloudy days are visible where the gradients are approximately equal. The irradiation and therefore the temperature load on the outer wall is thus significantly higher in the west than in the east. However, these temperature gradients per se are not so high that such severe damage – crack through the entire cross-section of the wall – would only point to this cause. More likely is a superposition of an unknown constructive weakness (impact of window linings, possibly corrosion of steel elements, which were not inspected during renovation, etc.) upon the influence of temperature.



Temperature gradient (°C) between the surface (0mm) and 25 mm depth in the east and west wall of the tower over a period of 18 days. The time is given in hours since the start of the measurements. (Credit: John Grunewald and Hans Petzold, TU Dresden)

In order to investigate the cause more closely, it would be advisable to continuously record the length of the crack. Length measurements should be possible in the range of 10^{-2} mm or even more accurately and can be connected to the existing installed data acquisition system. Thus, diurnal and annual influences of the climate will become evident.

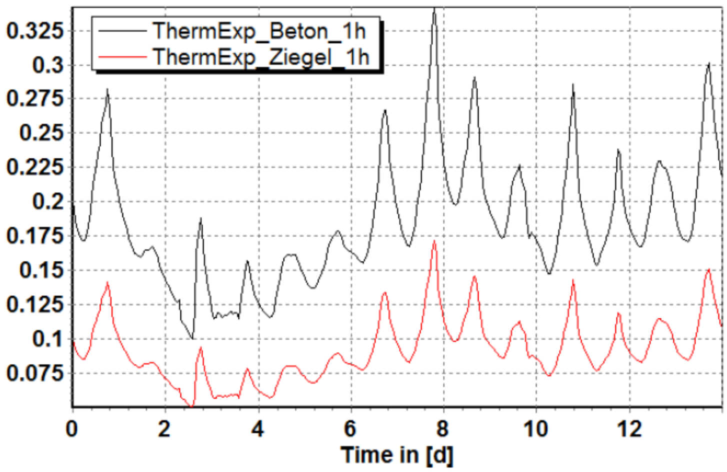
Tower Wall at the Sand Joint between Masonry and Concrete Ring

The transition from the tower to the dome is a constructive problem, since here the masonry of the massive tower wall meets the concrete ring of the dome base. Even if the concrete does not meet today's criteria, its thermal expansion should be about twice as high as for bricks. For historical bricks, 0.0036–0.0058 mm mK^{-1} are given in the literature, for concrete 0.009–0.011 mm mK^{-1}, and for cement mortar 0.01–0.012 mm mK^{-1}. Thus, approximately 0.005 mm mK^{-1} for bricks and 0.01 mm mK^{-1} for concrete is a reasonable assumption.

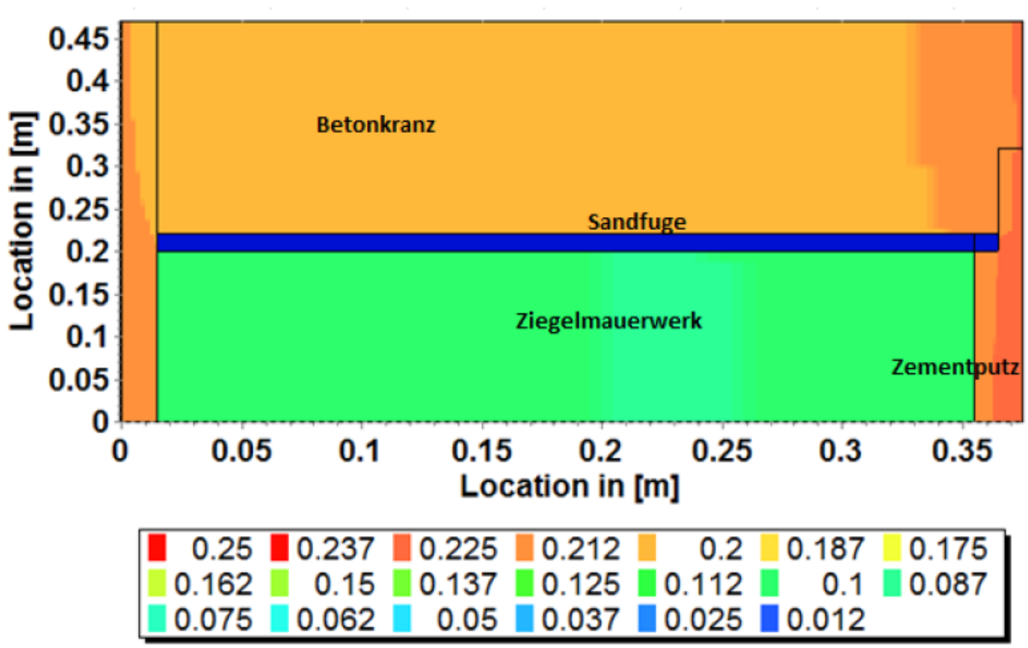
A temperature amplitude of 50 K in the course of the year therefore lead to an expansion of 0.2 mm for an effective length of 1 m. In the case of hard rendering, cracks can develop over time, which then quickly absorb penetrating water from driving rain. Normally, such a material change requires an expansion joint with a corresponding profile. The reconstruction of this detail adhering to monument protection guidelines and laws obviously produced the desired success.

Roof above Office at Upper Floor

An upper limit of the room temperature at 15 °C has been specified for the room at the upper floor, since there is a risk of condensation on the outside or underneath the ceiling. Two risks are to be considered: (1) surface condensation inside due to insufficient thermal insulation of the ceiling; and (2) condensate inside the ceiling, between the ceiling structure and the vapor-tight roof sealing. In both cases, in addition to the thermal insulation of the roof, the indoor climate plays a decisive role. Based on a calculation following the method of Glaser, under standard residential climate of 20 °C and 50% humidity, impermissible and dangerous condensation occurs in the winter, but states that under the assumption of leaky windows 14 °C and 40% humidity are permissible. However, the basis of this assumption is not further elaborated.

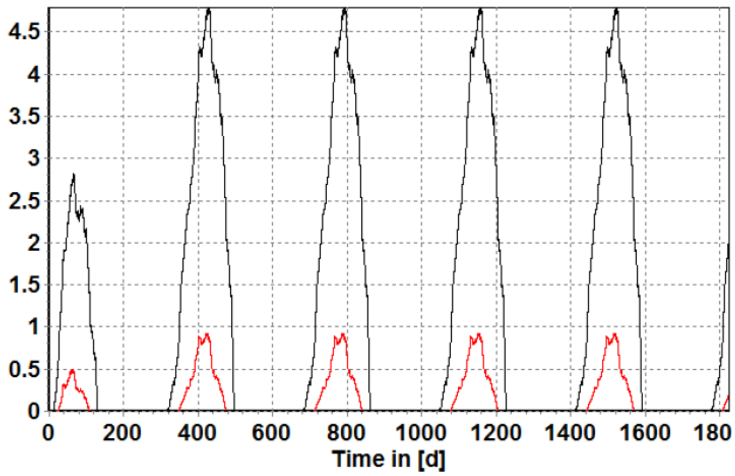


Thermal expansion (millimeters) of concrete and bricks over a period of 14 days. (Credit: John Grunewald and Hans Petzold, TU Dresden)

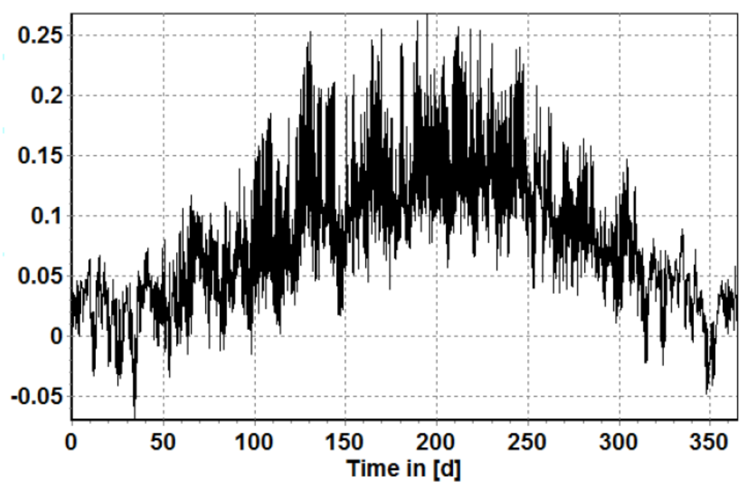


Two-dimensional thermal expansion (millimeters) of the concrete ring, sand joint, brick wall, and concrete render for a typical summer day. (Credit: John Grunewald and Hans Petzold, TU Dresden)

Decisive is not the temperature or the relative humidity, but the total moisture contained in the room air as water vapor. This depends, in turn, on the moisture sources in the room air and the air exchange. The absolute humidity of the room air at 14 °C and 40% humidity is approximately half of the standard living room climate (7.2 g kg^{-1} vs. 3.9 g kg^{-1}). Since the use of the space is only temporary and little moisture is released, whereby there is a sufficient change in the basic air due to the leaking windows, this assumption should be approximately valid. If the room air with 14 °C and 40% humidity is warmed up for example to 20 °C, the absolute moisture content remains constant and the relative humidity drops to approximately 27%. A limitation of the room temperature is therefore not necessary, however, a limitation of the absolute room air humidity is advisable.



Condensate mass under the roof covering in indoor climate 20 °C and 50% (black) and 20 °C and 40% (red line) in kg m^{-2} over five years. In the first year a "transient oscillation" occurs due to the start conditions of the simulation. According to moisture protection elaborated in DIN 4108 (so-called glazier proof) 0.5 kg m^{-2} would be permissible. (Credit: John Grunewald and Hans Petzold, TU Dresden)



Temporal evolution of the thermal expansion (mm m^{-2}) of the bricks under the sheet metal roof during the course of the year. (Credit: John Grunewald and Hans Petzold, TU Dresden)

A simulation with real climate conditions shows that the design has some reserves in practice. At 20 °C and 40% humidity, the condensate volume would be a little less than 1 kg m^{-2} at a real outdoor climate. Since an adjacent layer is not absorbent, only 0.5 kg m^{-2} would be permissible according to the German standard DIN 4108. Due to the solar radiation impinging on the level roof during the warm seasons, the (calculated) moisture dries well and there is no continuous build up in the following years. With the more realistic 14°C and 40% mentioned above no condensate would occur.

Since the real temporal course of the room air humidity and temperature is not known, these characteristics of the room have been included in the data collection. This ensures long-term safety against room air humidity exceeding critical values.

Under real conditions of use no damage is to be expected due to surface or internal condensation. If, during a new roofing, an insulation (a few centimeters thickness) is placed under the roof seal, which would also be sensible as summer heat protection, a vapor barrier should be installed on the "warm" side of the insulation.

The thermal expansion of the roof depends directly on the temperature. In the course of the year the calculated (free) stresses are shown in the report. According to the assumed absorption coefficient of the roof, they show an annual amplitude of approx. 0.3 mm m^{-1}.

If this expansion is hindered by the edge enclosure, corresponding forces will occur which, as a rule, must be absorbed by a tensile reinforcement in the case of a concrete component. The balustrade part of the Einstein Tower appears to be sufficient strong to serve this purpose. The water damage on the ceiling in the upper office suggests rather a sealing problem. However, this particular area is damage prone and should be checked regularly for cracks during the maintenance schedule.

Heating and Ventilation in the Einstein Tower

Compared to the original situation, there are only minor changes in the operation. Room conditioning has to ensure the conditions which are necessary for the utilization and at the same time to avoid harm to the building due to inappropriate parameters. This involves four factors: heating, ventilation, utilization, and heat protection of the building. Usually, heat protection is considered as heat insulation of the external components, but in case of historic buildings the thermal storage capacity comes into play.

In the tower, which is not heated at all, the temperature should vary as little as possible. This is accomplished by the relatively large thermal storage capacity of the tower, the small windows which are directed mainly to the North and the bright color of the outside surface. Effects from the operations are a minor heat and humidity input from the working rooms and weather-depending opening times of windows and the dome. The conditions, which are necessary for solar observations, are thus generally favorable for the building. The water gutters and collecting containers at the windows in the tower are a precautionary measure and originate from experiences with residential or public buildings gained in the construction time. In the Einstein Tower, the amount of humidity has been very low over all the years.

The working rooms are not used continuously and therefore have a temporal electrical heating. From the current point of view, it is worthwhile considering a better heating system in terms of energy efficiency and comfort. These rooms do not have any heat insulation in modern sense, except a few centimeters of plates from pressed turf in parts of the building. Together with the historic windows this causes a high energy consumption when the rooms are used. However, this is a temporary effect concerning limited areas.

Installing a gas heating is no option due to monument protection reasons. Alternatively, a connection to a local heating network of the nearby PIK institute building was considered. The available temperature level would be in the range 40–45 °C. Hence a heating may only be realized with large heating areas like a floor heating. Such a system is thermally inert and thus not appropriate for temporal using periods as it requires a pre-heating time. If the external heat is available at low cost, the basic room temperature could be constantly and incrementally raised. Such a generally higher temperature would reduce the range of temperature and humidity variations in the building and thus provide an additional safety against climate-caused humidity damages. However, this is not a general problem in the Einstein Tower.

The total electric energy consumption for the Einstein Tower in 2013 and 2014 was about 37,000–46,000 kWh per year. Subtracting the power consumption for instrumentation and illumination, we may estimate the electric power necessary for the heating as 20,000–30,000 kWh per year. This corresponds to the range of a typical not-reconstructed family home.

Consequently, it needs to be decided (1) whether a panel heating system can be installed properly in this monument (considering a floor heating, necessary pipes), (2) whether heat is available from a close-by source, and (3) whether this makes sense from the energy and economical point of view (including connecting pipes etc.).

Considering the temporal operation and the priority of the monument protection it seems appropriate to continue the electrical heating. The basement level is intrinsically thermally quite stable. The comfort in the upper working rooms may be improved by upgrading the leaky windows or/and heating plates at the working places.

Ventilation is required for removal of humidity and pollutants. The necessary amount of ventilation is therefore depending on the humidity production – which is low because there are only very few people in the rooms. In the upper rooms, the ventilation is provided by the leakage of the windows and doors and requires no extra measures. In the basement laboratory the user can manually activate a ventilation system if the humidity is too high or the air quality is poor. Since this is rather a short-time measure, there is no considerable heat loss. Particularly in winter, the relative humidity is reduced fast. Generally, such fast variations should be avoided in historic buildings, but in the case of the Einstein Tower there is no sensitive interior and the effect is not critical. A better regulation of the humidity considering the outside conditions would be possible using the installed sensors. The ventilation system is also used to remove the humidity from the gallery surrounding the spectrograph room. This room is also equipped with dehumidifiers. The amount of collected water is documented as a function control.

Regarding all these points and considering the aspect of monument protection, there is no need for action in the building. The ventilation and the electrical heating are not energy efficient in the modern sense, but work appropriately and are in agreement with the monument conservation requirements.

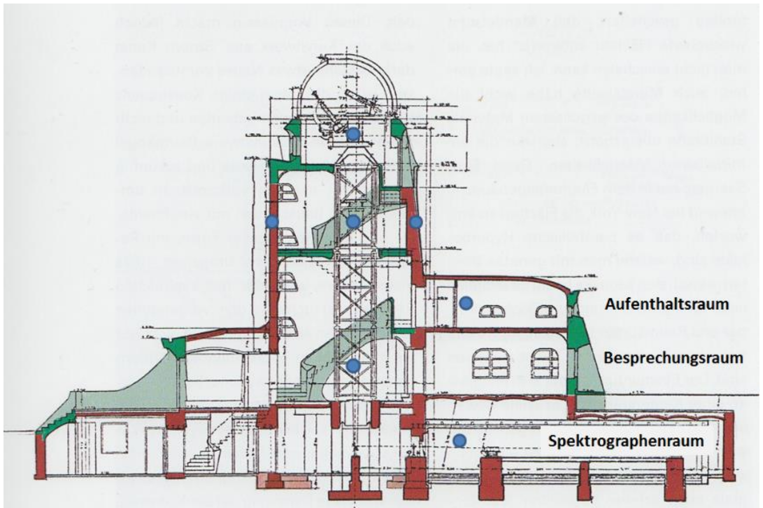
The real danger of moisture damage is by penetrating humidity from outside through cracks or defective sealing details. This is not subject of this investigation. The obviously exemplary renovation of the tower and the care plan prevents moisture damages. A visual impairment is due to algae growth on the facade. This happens at many buildings, but becomes very obvious here because of the bright painting of the tower. Clearly, all surfaces which are not rain-protected are inhabited by algae. Additionally, the partial shading by the trees delays the drying off. To prevent this effect, algaecide paints have been used for new buildings in recent years. For the algaecides effect, components must go to solution and thus are washed out. Hence, the algaecide effect is reduced over time and in addition a sometimes considerable groundwater pollution takes place. Independent authorities therefore recommend to avoid such paints as much as possible, or if unavoidable, to use so-called encapsulated biocides.

A functional damage due to the algae is not to be expected, so that the decision for the intervals of paint renewal can be justified at first purely by the optical appearance. Algae on facades are the subject of current research. Therefore, an exchange of information with practitioners is recommended to choose suitable algae removal measures and color on the monument to be able to comply with longer intervals for repainting.

The turf cover leads up directly on the exterior walls in the base area. This might cause an increased moisture penetration into the base due to the contact to moist soil and splashing rain water. From a technical point of view, a narrow gravel strip around the building could be useful.

Measurements of Temperature and Humidity

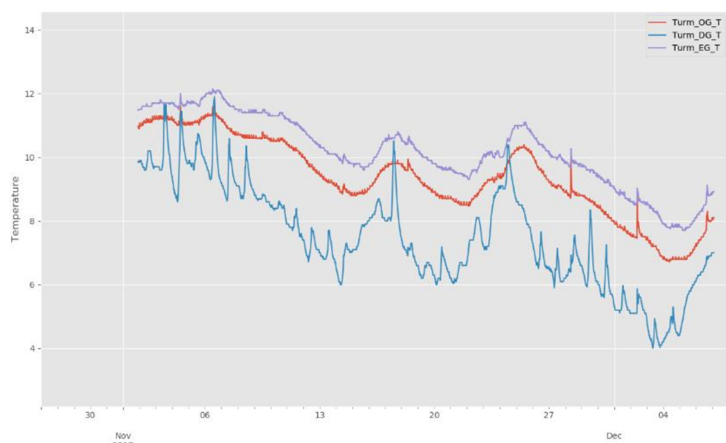
A reasonable estimate of the temperature generated stress is difficult because of the described uncertainties. Hence, we decided to record actual values at selected positions over a longer period. This provides us with parameters for the simulations and should also allow us to evaluate the effect of future heating and ventilation systems. A system of temperature and humidity sensors was installed: (1) inside the tower the air temperature is recorded at three levels, and the surface temperature is measured above the platform (lens level) in the four major compass directions, (2) temperature and humidity sensors were placed in various locations of the laboratory, the working rooms, and the meeting room, and (3) the surface temperature is measured on the exterior of the tower in the four major compass directions. The data is collected



Measuring points for temperature and humidity are marked by blue circles. (Credit: John Grunewald and Hans Petzold, TU Dresden)

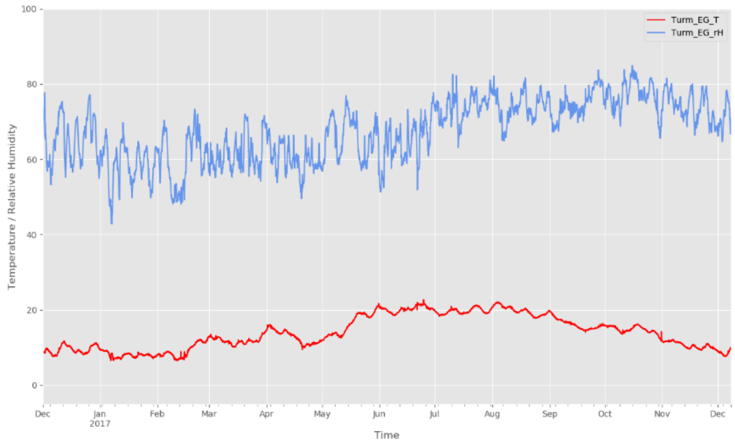
every 5 minutes and automatically transmitted and checked. A continuous measurement over a period of more than a year is recommended. First data have been measured and are used as input values for the simulations. A general evaluation of the measurements makes sense only after several months.

Data of the temperature (1Wire) and humidity (DHT 22) sensors are collected at one-minute intervals via two small Raspberry computers. The data are automatically transmitted to the TU Dresden via the Internet. Due to a cable problem, there was a temporary failure of the indoor air temperature and humidity data in the tower, which are evident in the measured data. At the beginning of December 2017, the temperature sensor on the west side of the tower failed. Occasional outliers occurred, which were corrected before the evaluation. Apart from this, all values are available at a one-minute resolution, which even makes brief radiation events visible. In general, however, the building is thermally inert so that an evaluation interval of 10 minutes or more is sufficient.

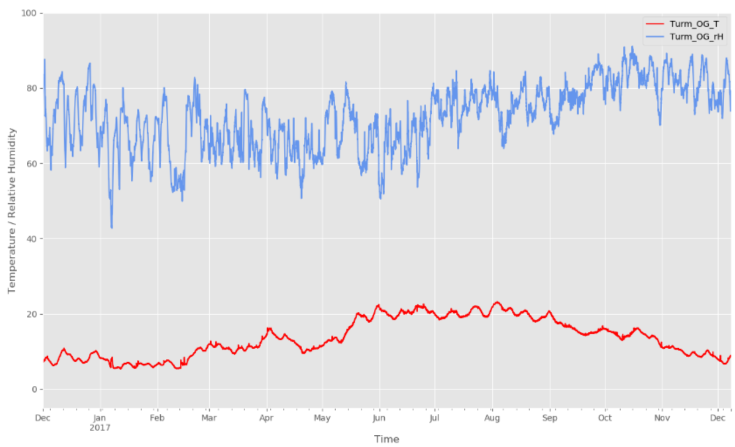


Typical air temperature (°C) measured at three different heights inside the tower in November/December 2017: ground floor (black), upper floor (blue), and dome (red). (Credit: John Grunewald and Hans Petzold, TU Dresden)

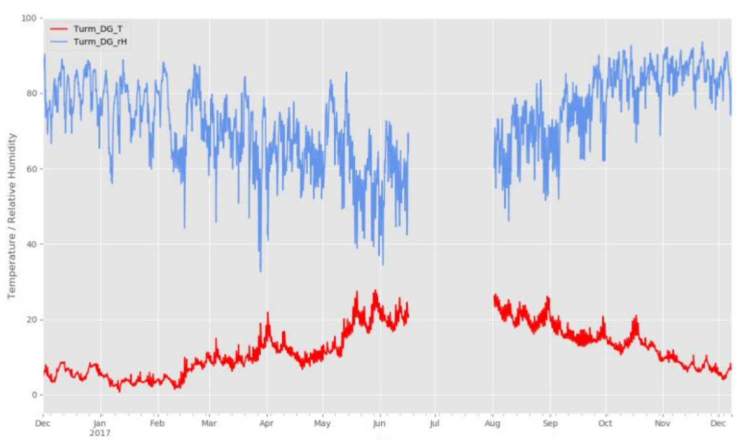
As expected, the air temperatures in the tower, measured at three heights, show a seasonal dependence. Stratification. In the cold season the temperature decreases from the bottom to the top, in summer the highest temperatures occur under the dome. On the ground floor and upper floor of the tower, the environment is quite stable, with higher fluctuations occurring under the dome. The relative humidity readings are shown in the following individual diagrams with the respective temperature. They are also relatively stable; under the dome, the coupling to the outside climate is stronger and the fluctuations are more pronounced and clearer. As an example, the following diagram shows a period from November 2017 in more detail. The temperature decreases upwards, the higher daytime fluctuations in the dome are clearly visible due to the influence of the climate caused by solar exposure, lower storage mass, and air leaks.



Air temperature (°C, red) and humidity (%, black) measured at the ground floor inside the tower. (Credit: John Grunewald and Hans Petzold, TU Dresden)



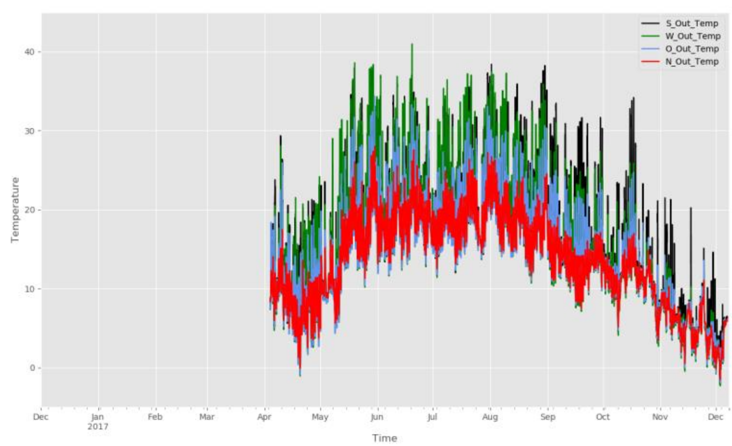
Air temperature (°C, red) and humidity (%, black) measured at the upper floor inside the tower. (Credit: John Grunewald and Hans Petzold, TU Dresden)



Air temperature (°C, red) and humidity (%, black) measured in the dome. (Credit: John Grunewald and Hans Petzold, TU Dresden)

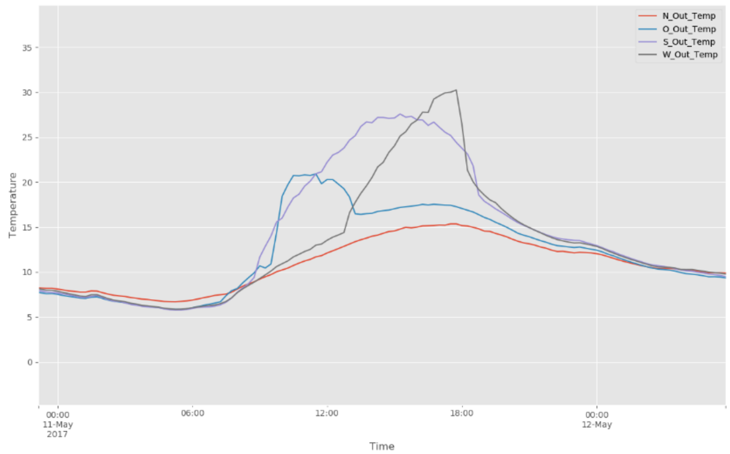
As expected, the temperature differences on the inner wall surfaces are very small. In the warm season, the internal surface temperatures are almost the same. In cold periods, the north wall is a maximum of 1 K colder. The outer surfaces of the tower show daily fluctuations that vary in intensity according to the illumination by the Sun. The north generally shows the lowest amplitudes, the east side is lit up on sunny days in the morning when the air temperature is even lower. South and west show the maximum values, analogous to the simulation results.

Surface temperature (°C) measured on the interior walls at the upper floor level (north = red, east = blue, south = black, and west = green). (Credit: John Grunewald and Hans Petzold, TU Dresden)



Surface temperature (°C) measured on the exterior walls at the upper floor level (north = red, east = blue, south = black, and west = green). (Credit: John Grunewald and Hans Petzold, TU Dresden)

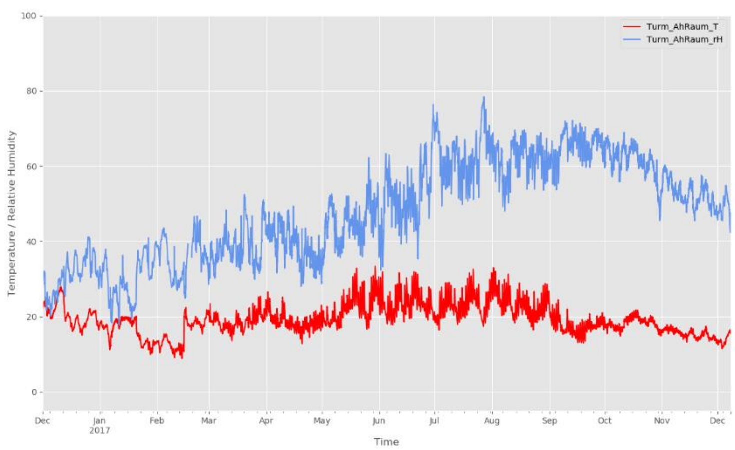
For clarification, a sunny day has been selected and is displayed below. The nightly temperatures are approximately the same on all surfaces. The sunrise takes place around 5:30 am. At this time the tower is obviously still shaded. From about 9:00 am on, in addition to the rise in air temperature, the influence of radiation can be seen: in the east it rises steeply until late morning, in the south it is spread more evenly over the day, in the west after the start of radiation exposure until the temperature drops rapidly after the absence of radiation. The higher thermal effect of the solar radiation on the west side, which is mentioned in the calculations, can also be seen here.



Typical surface temperature (°C) measured on the exterior walls at the upper floor level on 2017 May 12 (north = red, east = blue, south = violet, and west = black). (Credit: John Grunewald and Hans Petzold, TU Dresden)

Nevertheless, the maximum temperatures and gradients are moderate due to the light surface and the relatively fast drainage into the large thermal storage mass of the tower walls. On the day shown here, the maximum is about 30 °C. The highest measured temperature is about 40 °C, the lowest in winter just under 0 °C, with no distinct cold period occurring during the measurement period.

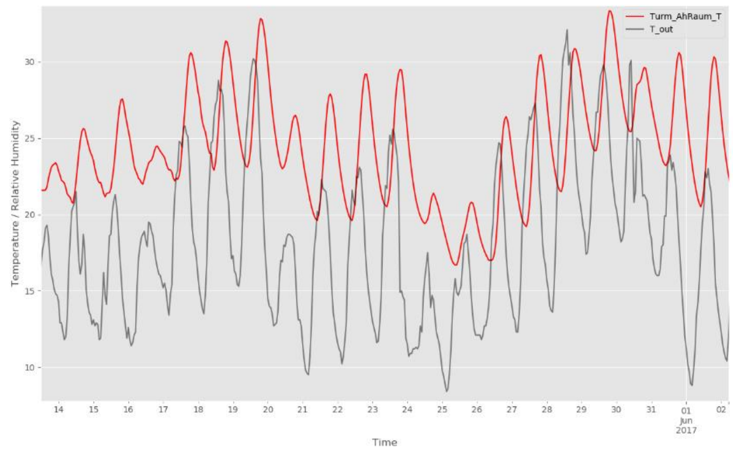
Room Climate Working Rooms



Room temperature (°C, red) and humidity (%, blues) measured in the office at the upper floor. (Credit: John Grunewald and Hans Petzold, TU Dresden)

During the course of the year, the air temperature is between 10 °C in mid-February and a maximum of approx. 33 °C in May to August. Therefore, the office at the upper floor does not only cool down moderately in winter; the jump from about 10°C to 20°C in mid-February is probably due to a corresponding temperature setting of the heating system by the users. The summer temperature is freely adjustable. The temperatures are not likely to be extreme for the building structure. However, for office work, the temperatures are clearly outside the comfort zone.

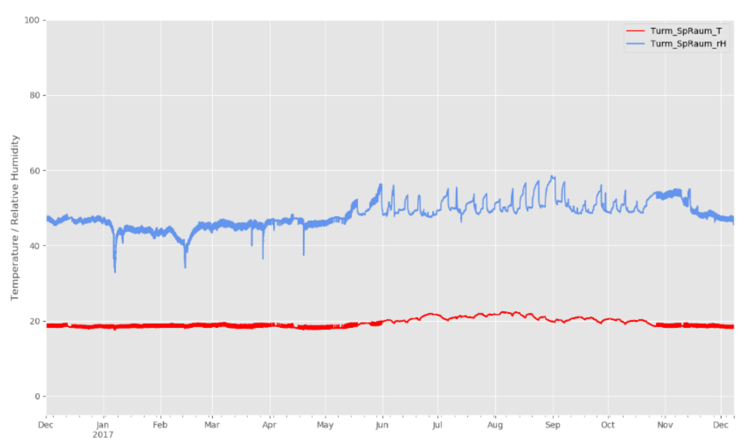
If one looks at the room temperatures with the outside air temperature in a heat period, here in June 2017, the room temperature during the day is about 3–5 °C above the outside air, which is plausible. At night, the outside air cools down considerably and is clearly below 20 °C. If night ventilation were possible, the room could cool down at night and a comfortable room climate would be possible, at least in the morning hours.



Room temperature (°C, red) measured in the meeting room at the ground floor level and outside air temperature (°C, gray). (Credit: John Grunewald and Hans Petzold, TU Dresden)

Room Climate Spectrograph Room

The temperature is almost constant throughout the year at about 20 °C. In winter, due to the temperature regulation, there are small short-term fluctuations, in summer the temperature settles freely, and it is only slightly above 20 °C. Even in the warm season, humidity typically does not exceed 60%, i.e., dehumidification obviously functions reliably. Only during extremely rainy periods, the relative humidity in the spectrograph room and the surrounding gallery may exceed 60% reaching up to 70%, even if all dehumidifiers are running. Of course, the variations of temperature and humidity are much lower in the spectrograph room itself.



Air temperature (°C, red) and humidity (%, black) measured in the spectrograph room. (Credit: John Grunewald and Hans Petzold, TU Dresden)

Summary and Recommendations

Due to the massive construction and the light-colored coating of the tower, the temperature loads of the construction during the day are comparatively low. Larger, albeit much slower, temperature amplitudes occur in the course of the year. A homogeneous design should be able to cope with this without much difficulty. However, the Einstein Tower is characterized by an inhomogeneous material composition and pre-damage, which is largely due to the original construction method.

If thermally induced stresses occur, cracks will initially appear at these weak points because tensile stresses cannot be absorbed sufficiently. Due to the many unknown factors, a deeper static analysis is a demanding and complex task. Based on the present study, the thermal loads are now known in detail for about one year, so that the boundary conditions for transient FEM calculations or similar are available. However, it is recommended to record and evaluate the measured data at least one year further.

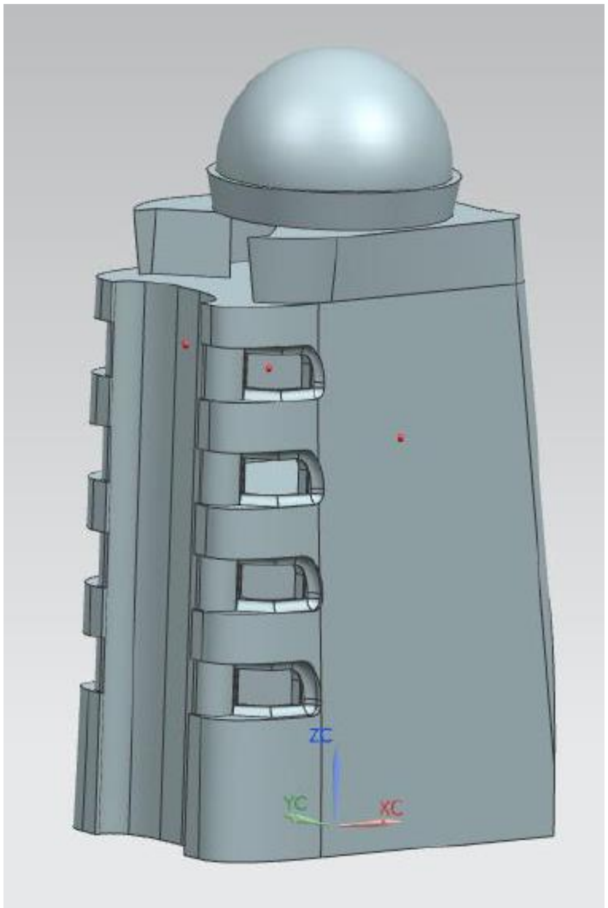
The assumptions and calculations of the previously performed numerical simulations of the thermal and moisture behavior are generally confirmed by the measurements. There is a certain improvement potential for a more comfortable indoor climate. Risks for the building do not arise from use, as the measured moisture input in the common rooms is low and is effectively limited in the spectrograph room and its surround gallery by dehumidification. Some areas are more exposed to radiation, i.e., the roof over the upper-floor office with its adjoining connections, the tower annex and, to a lesser extent, the west side of the tower. These are exposed to a higher risk of temperature-related damage. Within the framework of the implemented conservation plan, these are continuously monitored. It can be assumed that the crack sizes differ between summer and winter and are more pronounced in winter. This should be taken into account when planning and documenting inspections.

Three-Dimensional Model of the Einstein Tower

For the thermal modelling and better understanding of problems in critical sections of the building, a 3D model is considered to be very helpful. Transforming the existing drawings in a 3D model is very expensive. An alternative is a complete scan of the Einstein Tower from inside and outside. For this purpose, we contacted an experienced company specialized in 3D-laser scanning for survey and documentation of complex structures, for architects and monument conservation (Planungsbüro Matthias Grote, www.3D-laserscanning.com). They offer the measurement of the entire Einstein Tower including detailed measures of all floor levels with their architectural constructions (walls, floors, ceilings, columns, supports, windows, vents, doors, openings and visible risers). From the 3D-data, 2D-floor plans can be generated which include all current deformation information within 2 cm accuracy. This 3D-model can be combined in the future with the GWT-TUD test model, which simulates the thermal stress caused by the solar radiation as measured at selected positions of the tower during the course of the year and the day. The costs for the 3D scan were not included in the initial budget submitted to the Getty Foundation. Thus, a much simpler model was developed by GWT-TUD.

A long-term goal of the scientific investigations at the Einstein Tower was the structural modelling of the building with an FEM-model. The theoretical stresses in the material due to external loads such as climate, wind, and snow or structural loads can be calculated by means of a simulation. Since the real conditions in terms of both material and previous damage are not completely known and cannot be reproduced, this will always remain an idealization.

In addition to the load values and material parameters mentioned above, geometry is the most important input variable for such calculations. A three-dimensional model also offers the possibility of visualization. Therefore, three-dimensional model of the tower was created in addition to the building physics investigations.



Northwest view of the three-dimensional model of the Einstein Tower, where the locations of the temperature sensors are marked with red dots on the northern and western walls as well as on the interior of the eastern wall. (Credit: John Grunewald and Hans Petzold, TU Dresden)

Geometric Model

The complex geometry of the Einstein Tower was modelled with the commercial 3D CAD software NX-Unigraphics 11. The focus was on the main vertical structure of the Einstein Tower. The basis for this was provided by construction drawings of the building, subsequently produced external drawings, which were presumably drawn in 1998 during the damage analysis using photogrammetry methods, as well as measurements taken by on site.

The three-dimensional model is currently limited to the main vertical structure of the Einstein Tower, because on the one hand most of the attached temperature sensors and the most obvious damage to the building, i.e., a crack in the area of the third north-western tower window, were located in this area. On the other hand, on closer examination, this area is the one that can be mapped with justifiable effort using standard geometrical methods in conventional CAD construction tools. However, even with some details of the connection to the dome and the south balcony, it is evident that the Einstein Tower must be regarded as an artistic sculpture.

Prospects

In order to extend the three-dimensional geometric modeling of the entire building, the geometry has to be capture by means of a three-dimensional scan. The state-of-the-art for this is laser scanning, possibly with the support of multi-copters drones. The resulting point clouds have to be processed afterwards in order to generate surface or volume models. In addition to a commercial supplier, the Institute of Photogrammetry at the TU Dresden is a competent partner who can use a laser scanner to reproduce at least the outer geometry and thus the most demanding part of the geometry with high precision. Experimentally, it is possible to record a geometric data with a camera using a depth sensor, which is available at the Institute for Building Climate Control as part of an ongoing research project.

Heating Concept for the Einstein Tower

The heating concept for the Einstein Tower was developed by Dipl.-Ing. Markus Wolfsdorf in cooperation with the architect Helge Pitz. The heating concept will be adapted to the typical usage of the observatory and has to be confirmed by the State Office for Monument Protection (Landesamt für Denkmalpflege) in Brandenburg. Based on the building-physics investigation by the Institute for Building Climate Control at the TU Dresden focusing on the thermal and humidity behavior of the historical construction of the Einstein Tower, it can be assumed that the rooms in the building should be heated to a room temperature of +15 °C to +20 °C, depending on their use.

The heating has to be carried out with electrically operated radiators due to the smallest possible structural interventions in the building structure. The heating load is estimated at 45–50 kW. The electrical supply is to be implemented via an existing medium-voltage system with underground electrical cables to the Einstein Tower and an existing low-voltage sub-distribution.

The services required for the production of the stationary heating system include the inventory of the room and component dimensions for heating load calculations as well as a heating load determination according to DIN EN 12381. Possible cable paths, installation areas of the heating elements or radiators and the low-voltage sub-distribution must be recorded and coordinated with each other. Static possibilities must be checked to see whether they are suitable for the renewal of the electric cabling within the masonry walls, because of the now necessarily insulated version of the electric cabling. Any necessary fire protection measures must also be checked as part of the cable installation. The next steps require the creation of design and construction drawings as well as functional diagrams. This is followed by the preparation of documents for tender and the corresponding award documents.

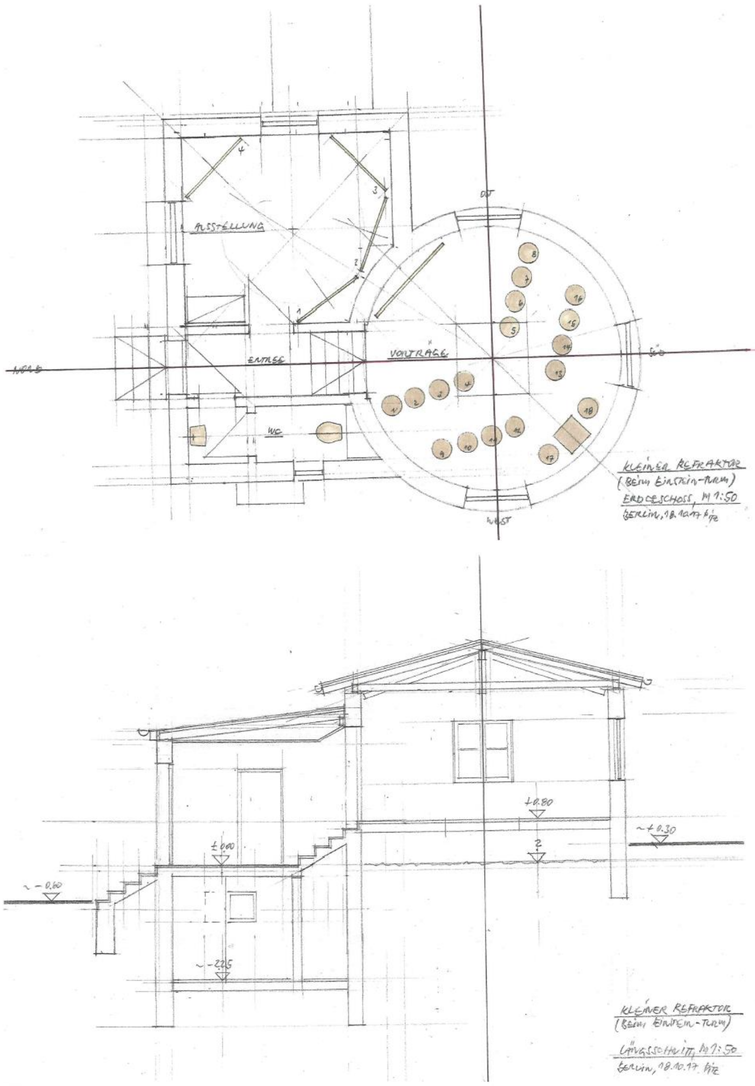
Restoration of the Small Refractor Building

After relocation of all staff to the Babelsberg campus of the Leibniz Institute for Astrophysics Potsdam, some buildings were no longer used by the Institute. In close proximity to the Einstein Tower, a building, which hosted a small refractor in the past, contained office space for AIP's research section Physics of the Sun. In the following, we describe a proposal to restore and adapt the currently unused building so that it can house a permanent exhibition of the Einstein Tower, provide audio-visual equipment to present information to guided tours, and offer meeting space for small groups and small events.

In the following, we provide a description of the object and its condition as well as necessary repair measures and the possibilities of a new use. Only 50 m away from the Einstein Tower, the building is overgrown in the forest. The dome has been replaced by an emergency roof, and the original refractor is no longer mounted inside the dome. An overgrown path leads from the Einstein Tower to the Small Refractor building.

The basic substance of the building is worth preserving. Exterior and interior plaster as well as floors are moistened. The roofs of the former observing room and the adjoining flat building are moistened and affected by fungal infestation (serpula lacrymans). However, the wooden doors and windows are in a condition, where a restoration is possible. Vertical moisture insulation will become necessary on the outside, especially where the building is below ground.

The restoration measures require the building to be excavated all around. The exterior walls in the ground must be covered with insulating plaster and moisture insulation. The exterior plaster must be taken off and completely replaced. The interior plaster must also be completely removed and renewed. The emergency roof no longer meets today's building requirements and must therefore be replaced, in particular a thermal insulation must be installed that meet today's building standards. The floors must also be removed. New screed has to be laid and a new linoleum flooring has to be placed in all rooms. New coats of paint are required for all walls in all rooms and for the corresponding newly installed false ceilings (hallway, WC area, exhibition room, former observing room, and all rooms in the basement). Windows and doors have to be reworked by carpenters and repainted. The path to and around the building must be prepared with the help of a garden architect.



Floor plan and section drawing of the Small Refractor building near the Einstein Tower. (Credit: Helge Pitz)

The concept for the new use of the building includes the furnishing of the former observing room for lectures, scientific talks, etc. With the simplest furnishings, it is possible to accommodate 18–20 persons and to set up a video beamer with projection screen. The adjoining room is ideally suited as an exhibition space in which the scientific use of the Einstein Tower (historical and present day), the 90-year history of its restoration as well as the personalities Albert Einstein, Erwin Finlay-Freundlich, and Erich Mendelsohn are represented. The building will provide space for visitors from all over the world who are interested in the innumerable aspects of architecture and will receive an introduction and/or photo presentation. This also benefits our long-standing partner, Urania Potsdam, who is heavily involved in public relations work on the Telegraphenberg. In addition, the building enables scientific meetings of astrophysicists and their guests on a small scale. The remote location and the distance to the Babelsberg campus of AIP offers an environment for undisturbed working away from the daily routine.

Immediate Repairs in 2018

The Einstein Tower displays some significant damages at the interface between tower and the roof covering the office space, so that water can penetrate into the wall. This led to moisture damages under the ceiling and along the windows. Other problematic areas include the small roof just above the entrance and the interface between tower and dome. Removal of the existing Triflex insulation and careful cleaning of the surfaces is required so that proper bonding is assured when installing the new Triflex insulation. Particular attention has to be paid regarding the transitions between the sheet metal roof areas and the Triflex seals, as structural problems of the current interface led to water penetration and moisture damages. To restore the Einstein Tower scaffolding will be need in the affected areas on the north and south sides of the building. In addition, inspection of hard-to-reach spaces will be done with a vehicle-mounted aerial work platform, which will also allow the specialist company to seal cracks and fix damages at locations, where the plaster and rendering broke of the exterior walls. The work platform will also be used to clean all exterior walls and restore the ochre-colored painting of the render. All work has to be coordinated with the State Office for Monument Protection (Landesamt für Denkmalpflege) in Brandenburg and is scheduled for immediate remediation in the second and third quarter of 2018.

Summary of the Project

The planning grant of the Getty Foundation allowed us to address three major tasks: validating that the original long-term conservation plan is effective, developing a heating concept for the Einstein Tower adapted to its specific usage, and hygrothermal simulations of the most damage prone structures of the Einstein Tower supported by precise measurements of the temperature and humidity conditions inside and outside the building.

We have obtained detailed architectural and engineering plans to carry out the work (including estimates of work effort and costs), restoring the Einstein Tower to a healthy condition for the years to come. In addition, we included a proposal for the restoration of the nearby Small Refractor building, which has the potential to become an exhibition space and a place for scientific meetings. Both types of usage will enhance the Einstein Tower experience for visitors of guided tours and for scientific guests of AIP and the other research institutes on the Telegraphenberg.

Currently, we are in the process to identify funding for the restoration of the Einstein Tower and also for the Small Refractor building. First contacts with the Wüstenrot Foundation, which also generously supported the last major restoration of the Einstein Tower, have been positive. With the results of the Getty Foundation planning grant, we have now the documents at hand, which hopefully allow us to realize the outcomes of this study.